National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Monitoring Kittlitz's and Marbled Murrelets in Glacier Bay National Park and Preserve

2012 Annual Report

Natural Resource Technical Report NPS/SEAN/NRTR—2013/810

ON THE COVER
Observers counting murrelets along a transect
Photograph by: Christopher J. Sergeant, Southeast Alaska Network

Monitoring Kittlitz's and Marbled Murrelets in Glacier Bay National Park and Preserve

2012 Annual Report

Natural Resource Technical Report NPS/SEAN/NRTR—2013/810

Steven T. Hoekman[1], Christopher J. Sergeant[2], William F. Johnson[2]

[1]Wild Ginger Consulting
705 N 50th Street, Suite 206
Seattle, WA 98103

[2]National Park Service
Southeast Alaska Network, Inventory and Monitoring Program
3100 National Park Road
Juneau, AK 99801

October 2013

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Technical Report Series is used to disseminate results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service mission. The series provides contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from the Southeast Alaska Network (http://science.nature.nps.gov/im/units/sean/KM_Main.aspx) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov**.**

Please cite this publication as:

Hoekman, S. T., C. J. Sergeant, and W. F. Johnson. 2013. Monitoring Kittlitz's and marbled murrelets in Glacier Bay National Park and Preserve: 2012 annual report. Natural Resource Technical Report NPS/SEAN/NRTR—2013/810. National Park Service, Fort Collins, Colorado.

NPS 132/122657, October 2013

Contents

Page

Figures

Page

Tables

Page

Executive Summary

Since 2009, the National Park Service's Southeast Alaska Inventory and Monitoring Network (SEAN) has monitored population abundance and trend of Kittlitz's (KIMU) and marbled murrelets (MAMU) in Glacier Bay National Park and Preserve, an important summer residence for both species. This annual report summarizes data in a concise format and focuses on current population abundance and spatial distribution.

Monitoring focuses on KIMU, with secondary consideration of MAMU. KIMU are an open-water, pursuit forager whose reliance on pelagic prey sources link their habitat use in some areas to dynamic physical habitat variables such as glacial extent and oceanography. Previous studies in Glacier Bay suggest recent declines in KIMU populations, but uncertainty persists due to methodological differences across surveys. SEAN uses boat-based line transect surveys to estimate species-specific, on-water density and abundance of murrelets, accounting for detection probability and unidentified murrelets. We surveyed 245 km on 45 transects from 8-16 July 2012 across the 1,170 km^2 survey area in Glacier Bay proper. We estimated an abundance of 16,469 KIMU (SE = 2,581) and 52,560 MAMU (SE = 5,216). From 2009 to 2012, KIMU abundance estimates have ranged from 7,477 to 16,469 with annual changes of -44% to 120%, while MAMU have ranged from 28,978 to 73,766 with annual changes of -29% to 113%. Such large variation was unlikely to reflect solely intrinsic population growth.

Monitoring in Glacier Bay confirms that the park supports an important fraction of the global KIMU population. After the 2016 survey, SEAN will synthesize existing abundance and trend information and re-examine analytic methods to assess if monitoring is likely to achieve program objectives. Our results to-date demonstrate that key operational components of our monitoring protocol are functioning as intended.

Acknowledgments

B. Moynahan played a lead role finalizing survey protocols and organizing pre-season logistics. R. Sarwas provided critical support for the NPTransect application. M. Kirchhoff provided expertise in surveys and dedication to improving the monitoring program. The Glacier Bay National Park and Preserve Visitor Information Station oversaw boating logistics and safety while conducting surveys. Glacier Bay staff, especially L. Sharman, L. Etherington, and A. Banks, facilitated our research in the park. S. Gende provided constructive comments on a prior version of the report.

Introduction

Since 2009, the National Park Service's Southeast Alaska Inventory and Monitoring Network (SEAN) has monitored population abundance of Kittlitz's (*Brachyramphus brevirostris*, hereafter "KIMU") and marbled murrelets (*B. marmoratus*, hereafter "MAMU") in Glacier Bay National Park and Preserve. The program arose from concerns over global and local KIMU declines, their status as a candidate species for protection under the Endangered Species Act (USFWS 2013), and the hypothesis that their populations respond to fluctuations in drivers of the Glacier Bay ecosystem. As part of its Vital Signs Monitoring Program, SEAN designated KIMU as a priority natural resource with the specific objectives of monitoring population abundance and trend and describing annual variation in population spatial distributions.

The KIMU is a seabird endemic to Alaska and northeastern Russia, with the highest breeding population densities in the northern Gulf of Alaska (Day et al. 1999). KIMU in summer are often associated with tidewater glacier and glacial fjord habitats, but also occur in non-glacially influenced areas (Day et al. 1999, Arimitsu et al. 2011, Kissling et al. 2011, Madison et al. 2011, USFWS 2013). KIMU often forage in proximity to glacier outflows (Day and Nigro 2000, Kuletz et al. 2003) and nest in recently de-glaciated areas with sparse vegetation (Day 1995, USFWS 2013). As a summer resident, open-water, pursuit forager, KIMU are likely to play an important role as integrators of variation in marine and terrestrial ecosystems and directly relate to the conceptual ecological models in the SEAN Vital Signs Monitoring Plan (Moynahan et al. 2008). Reliance on pelagic prey sources and glacially-influenced habitats link KIMU to dynamic physical habitat conditions such as glacial extent and oceanography that are, in part, subject to chronic changes due to climate change (e.g., Arendt et al. 2002).

Prior studies in Glacier Bay and the region have suggested recent declines in KIMU breeding season populations, but considerable uncertainty remains because of sparse data, high variability in estimates, and differences in methods (Hoekman et al. 2011b, c; Kuletz et al. 2011a, b; Piatt et al. 2011, USFWS 2013, Kirchhoff et al. In Press). Several challenges inherent to Glacier Bay and its murrelet populations complicate estimating murrelet abundance: difficulty distinguishing between the two cryptic species, incomplete detection of murrelets along transects, large spatial and temporal variation in populations, and convoluted topography that complicates survey transect placement.

SEAN monitoring focuses on estimating population abundance and trend primarily for KIMU and secondarily for MAMU. The 2009 and 2010 annual KIMU reports, in conjunction with the final long-term monitoring protocol (Hoekman et al. 2013a) provide complete protocol development details and fully describe monitoring methods.

These annual reports are designed to efficiently report data in a simple and concise format, focusing on population abundance and spatial distributions. Periodic syntheses at 6 year intervals will assess program performance and population trends. Our 2012 study objectives were to complete the fourth year of boat-based line transect surveys, estimate population abundance of KIMU and MAMU in Glacier Bay and describe their spatial distribution, and summarize results since 2009.

Methods

This methods section includes a brief overview of survey design, survey methods, and analytic approach. Full details can be found in the SEAN long-term monitoring protocol (Hoekman et al. 2013a); relevant protocol sections are referenced below.

Study area

Glacier Bay is a narrow, glacial fjord located in Southeast Alaska. The study area encompassed 1,170 km^2 of waters north of Icy Strait and excluded some areas designated as non-motorized waters or those that did not allow safe survey vessel passage (Figure 1).

See Chapter 1 of the SEAN long-term monitoring protocol (Hoekman et al. 2013a) and Hoekman et al. (2011a) for more detail.

Survey design

We employed a generalized random tessellation stratified sampling design (GRTS; Stevens and Olsen 2004) to minimize deleterious effects of large spatial variation in murrelet abundance (Drew et al. 2008, Hoekman et al. 2011a,b) by providing a random, spatially-balanced sample. We allocated survey effort relative to expected densities of KIMU using unequal probability sampling. To avoid placing transects parallel to the observed density gradient of murrelets (Drew et al. 2008, Kirchhoff 2011) and to provide representative coverage across water depths, we oriented linear transects perpendicular to the local prevailing shoreline. In more enclosed waters we used shore-to-shore zigzag transects to avoid undesirably short transects. Transects are sampled according to an augmented, serially alternating panel design (McDonald 2003), where one panel (set of transects) is sampled annually and three others are visited on a three-year rotation, with 2012 including the third panel.

See Chapter 2 and Appendix B of the long-term monitoring protocol for more detail (Hoekman et al. 2013a)

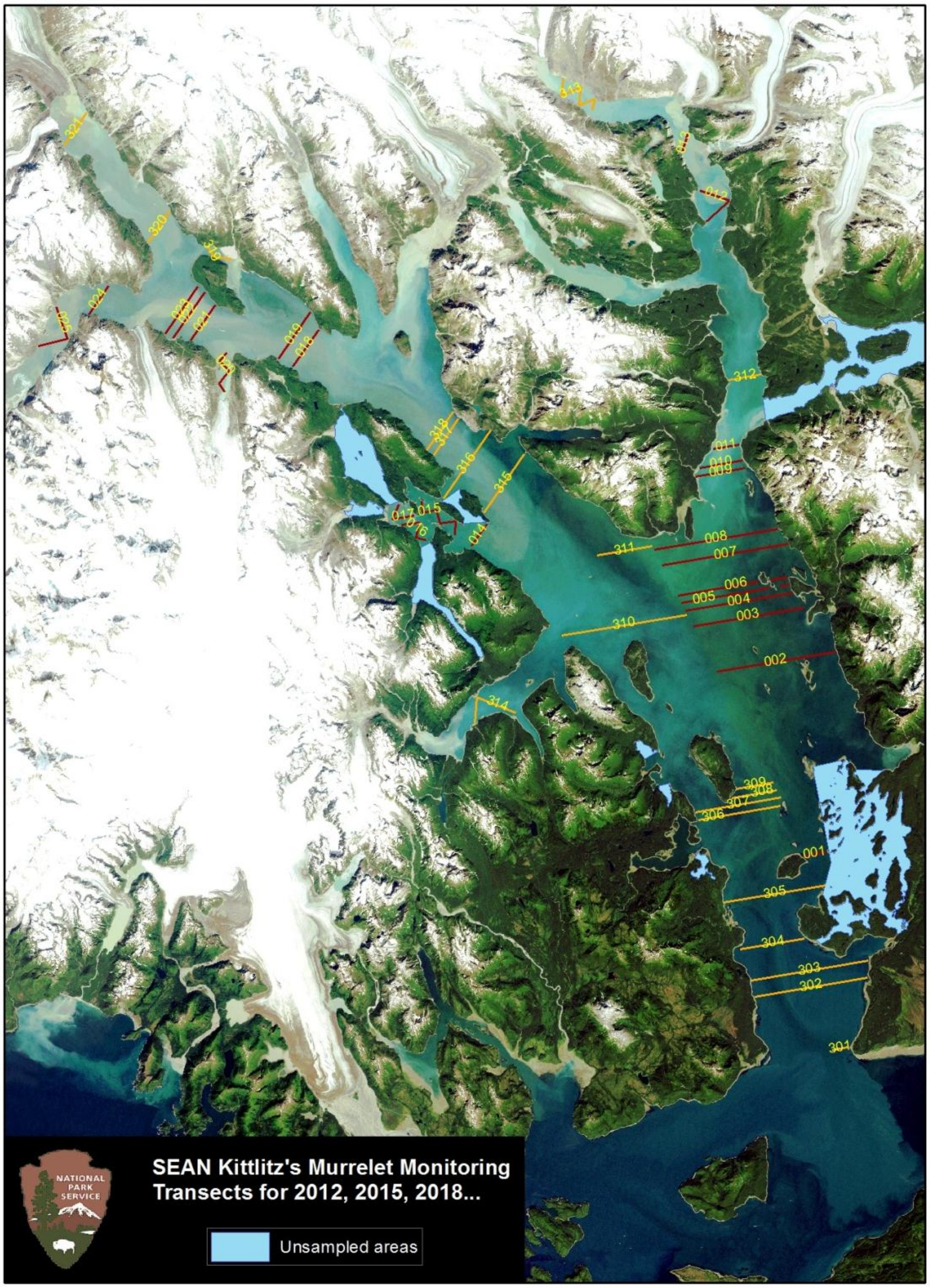

Figure 1. Line transects surveyed for murrelets in July 2012. Permanent (red lines) and Panel 3 (orange) transects were surveyed as part of an augmented, serially alternating panel design with a three-year rotation. Linear transects were used in open waters (>2.5 km wide) and zigzag transects were used in more restricted waters. Transects extended from shore to shore, except a few split into 2 at mid-Bay to maintain optimal transect length. Linear transects were oriented perpendicular to the prevailing shoreline. The orientation of zigzag transects relative to shore was determined by width of each area. Unsampled areas are highlighted in light blue.

Survey methods

We conducted boat-based line transect surveys (Buckland et al. 2001) at a speed of ≤10 km/h aboard the NPS R/V Fog Lark, an 8.5 m landing craft with a large front deck that provided a viewing height of approximately 3 m above the water line for two observers. For all groups (murrelets of one species class in a flock) initially located on the water, observers recorded group size, species class (KIMU, MAMU, or unidentified), and estimates of distance and angle from the boat. The allowable Beaufort sea state was ≤ 2. Program NPTransect (designed by R. Sarwas and W. Johnson, National Park Service) was used to record observations and associated GPS-based date/time/location stamps.

See the long-term monitoring protocol (chapter 3 of the narrative, Standard Operating Procedures, hereafter "SOPs," 1, 2, 3, and 9, and Appendix F) for more detail (Hoekman et al. 2013a).

Abundance estimation

We estimated detection probability and group size using Program DISTANCE version 6.0 (Thomas et al. 2010) and species-specific abundance using statistical software R version 2.13.0 (R Development Core Team 2008) following recommended distance sampling methods (Buckland et al. 2001) and protocol SOP 12 (Hoekman et al. 2013a). We modified distance sampling methods to account for incomplete detection near the transect center line and unidentified murrelets. Adjustments for unidentified murrelets assumed correct identification and identical proportions of each species in the identified and unidentified samples. Density estimates were based on several component parameters: detection probability across the transect width, detection probability near the center line, group size for each species class, and encounter rates for each species class. We estimated abundance by multiplying total study area (1,170 km^2) by estimated densities.

See Hoekman et al. 2011c and the monitoring protocol (appendices A and D, SOPs 11 and 12) for more detail.

Results

We surveyed 45 transects totaling 245 km from 8-16 July 2012 and detected 1,679 groups. Transect 025 was not surveyed due to heavy surface ice within Johns Hopkins Inlet. We classified 418 (23%) on-water groups as KIMU, 784 (44%) as MAMU, and 594 (33%) as unidentified. Detection probability was high within 200 m of the transect center line (71%; Table 1). Sixteen percent of all observations were made during Beaufort sea state 0, 54% at 1, and 30% at 2. A few observations (11) were recorded at sea state 3 on Transect 314. Re-surveying the transect at a calmer time was not feasible. Most observations (77%) were recorded with >50% cloud cover, with 19% recorded during rain or fog and only 4% with <50% cloud cover.

Our estimated effective strip width was 145 m. Estimated detection probability remained near 1 to approximately 60 m from the center line, but decayed rapidly at larger distances (Figure 2).

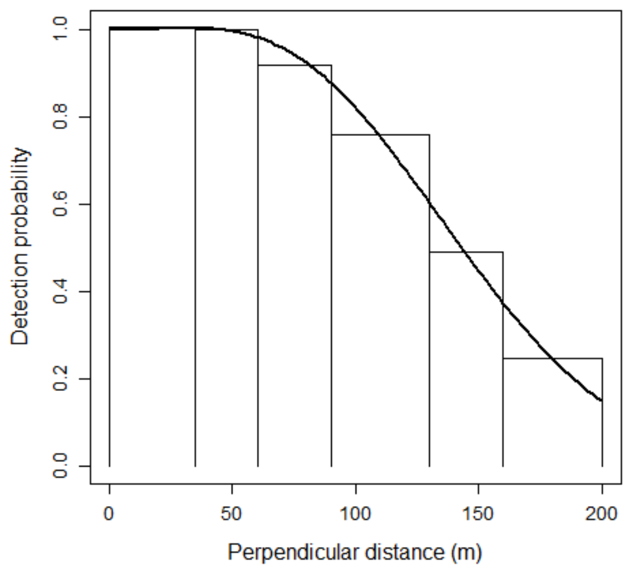

Figure 2. Estimated detection function for murrelets from line transect surveys in Glacier Bay, July 2012, illustrating detection probability of murrelet groups relative to the perpendicular distances from the transect center line.

Higher average group size and encounter rates for MAMU (Table 1) resulted in estimates of on-water density and abundance ~3 times higher than KIMU (Table 2). Precision of estimated abundance was higher for MAMU (CV = 0.098) than KIMU (CV = 0.156), primarily because of corresponding differences in CVs (SD/mean) for among-transect variation in encounter rates between species. Density estimates since 2009 (Hoekman et al. 2011a,b; Hoekman et al. 2013b) for each species show considerable imprecision and variation among years (Figure 3). Estimated KIMU abundance was much higher than in 2011 and slightly higher than 2009 and 2010. Estimated MAMU abundance in 2012 was lower than 2011 and was near the 2009-2011 average.

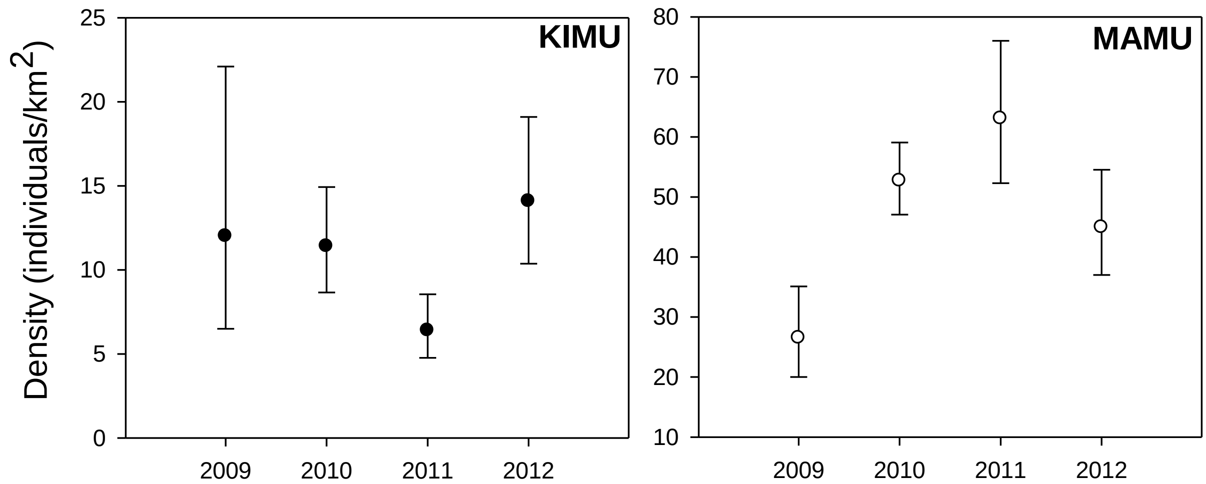

Figure 3. July densities (individuals/km^2) of Kittlitz's (KIMU, black circles) and marbled murrelets (MAMU, white circles) in Glacier Bay survey area from 2009-2012. Error bars are 95% confidence intervals. Note separate *y*-axes for density and that 2009 estimates were based on pilot survey methods (Hoekman 2011a). Densities are displayed to control for differences in survey area for 2009 (1,092 km^2) relative to 2010-2012 (1,170 km^2).

The distribution of KIMU within Glacier Bay was relatively patchy in comparison to MAMU (Figure 4). The highest KIMU densities were encountered around mid-bay, the Hugh Miller-Scidmore Complex, Reid Inlet, and southwest of Russell Island. MAMU were encountered throughout Glacier Bay, but densities were generally lower in the upper fjord heads of the west and east arms (Figure 5).

Table 1. Component parameter values used to estimate on-water density and abundance of Kittlitz's and marbled murrelets in Glacier Bay for July 2012. Group sizes were estimated as averages or from a regression accounting for a potential influence of group size on detection; one estimate was selected for each species class (see SOP 11 of protocol for more detail).

Parameter	Estimate	SE	*P*-value	Degrees of freedom
Detection across transect width	0.71	0.03		1,654
Detection near transect center line[a]	0.94	0.03		66
Group size: Average				
Kittlitz's murrelet [b]	2.11	0.08		360
Marbled murrelet [b]	2.41	0.07		716
Unidentified murrelet	2.93	0.15		517
Group size: Regression estimate				
Kittlitz's murrelet	2.04	0.06	0.19	359
Marbled murrelet	2.33	0.05	0.29	715
Unidentified murrelet [b]	2.42	0.08	<0.001	516
Encounter rate (groups/km)				
Kittlitz's murrelet	1.21	0.16		44
Marbled murrelet	3.39	0.29		44
Unidentified murrelet	2.09	0.20		44

[a] Estimate from Hoekman et al. 2011c.

[b] Estimate selected for estimation of density and abundance.

Table 2. Estimates of on-water population density and abundance of Kittlitz's and marbled murrelets in Glacier Bay during early July. Abundance was projected across surveyed waters only. Note that pilot surveys in 2009 differed in survey area (1,092 km^2) and methods (Hoekman et al. 2011a).

	Kittlitz's murrelet				Marbled murrelet			
Year	**Density[a]**	**SE**	**Abundance**	**SE**	**Density[a]**	**SE**	**Abundance**	**SE**
2012	14.1	2.2	16,469	2,581	44.9	4.5	52,560	5,216
2011	6.4	1.0	7,477	1,119	63.1	6.0	73,766	7,055
2010	11.4	1.2	13,308	1,357	52.7	4.6	61,717	5,372
2009	12.0	3.7	13,124[b]	4,062	26.5	3.7	28,978[b]	4,077

[a]Individuals/km^2

[b]Abundance extrapolated over 1,092 km^2 of sampled waters; all others extrapolated over 1,170 km^2.

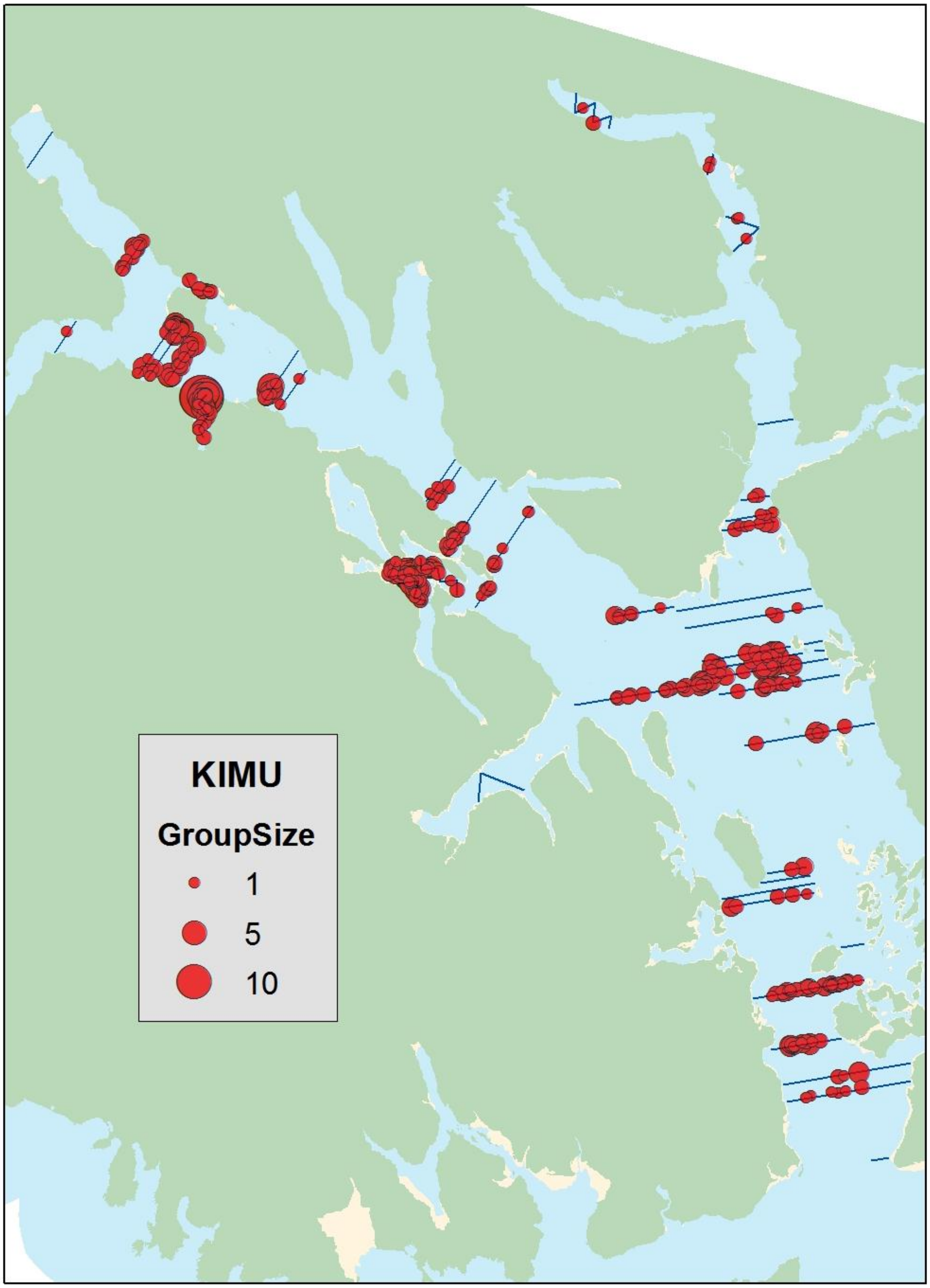

Figure 4. Spatial distribution of Kittlitz's murrelets observed during line transect surveys (blue lines) in Glacier Bay, July 2012. The area of symbols is proportional to group size.

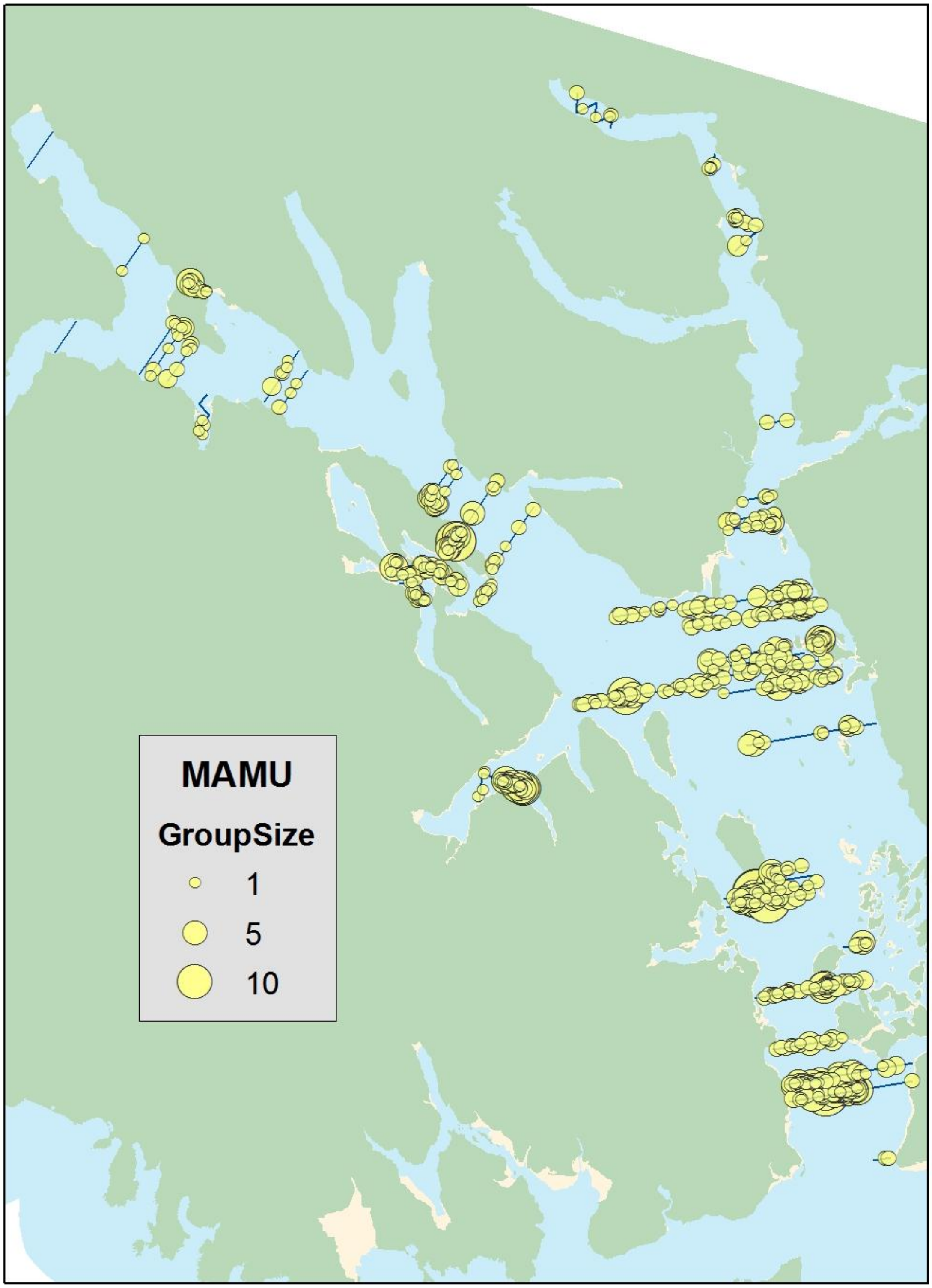

Figure 5. Spatial distribution of marbled murrelets observed during line transect surveys (blue lines) in Glacier Bay, July 2012. The area of symbols is proportional to group size.

Discussion

Abundance estimates

The July 2012 on-water abundance estimate for KIMU in Glacier Bay was markedly higher than 2011 and slightly higher than 2009 and 2010 (Hoekman et al 2011a,b; Hoekman et al. 2013b). From 2009 to 2012, abundance estimates for KIMU have ranged from 7,494 to 16,730 individuals, with annual change ranging from -44% to 120%. Given existing knowledge, the breeding season population of KIMU in Glacier Bay likely has exceeded others in Alaska (Arimitsu et al. 2011; Day et al. 2011; Kissling et al. 2011; Kuletz et al. 2011a,b; Madison et al. 2011) and comprised an important fraction of the global population (USFWS 2013).

Since 2009, estimates of on-water MAMU abundance in Glacier Bay have ranged from 28,978 to 73,884, with annual change ranging from -29% to 113%. For both species, change in abundance estimates between years appeared larger than could be attributed solely to intrinsic population growth. Effects of other potential factors contributing to changes in abundance estimates, such as change in proportion of the local breeding population on surveyed waters during sampling, immigration and emigration from and to other populations, or sampling error, remain unknown. As in previous years, abundance estimates for MAMU were higher and CVs were lower than for KIMU. Variance in encounter rates has dominated total variance of abundance estimates (Hoekman et al. 2011a, b, c), and relatively low precision of abundance estimates for KIMU reflected higher CVs for among-transect variation in encounter rates resulting from relatively aggregated distributions for KIMU.

Detection and identification

Our overall estimated detection probability for 2012 surveys (0.71) was comparable to estimates from 2010 (0.72; Hoekman 2011b) and 2011 (0.70; Hoekman et al. 2013b). However, a shorter right-truncation distance in 2012 (200 m vs. 230 m) and rapidly declining detection probability at distances >100 m indicated lower detection probability at large distances than in 2010 and 2011. Additionally, classification of murrelet groups to species was lower in 2012 (67%) than in 2010 (76%) and 2011 (78%). Both observers in 2012 had substantial experience with murrelet surveys in Glacier Bay; thus, we believe lower detection and species identification rates can be largely attributed to weather conditions. The high frequency of rain and fog conditions in 2012 was similar to 2010 surveys, but windy conditions (Beaufort sea state = 2) were far more frequent in 2012 (30% of observations) than 2010 and 2011 (5%). Wave heights of 20-50 cm can cause an unstable viewing platform and often only intermittent views of murrelets at the top of wave crests. These viewing challenges may be amplified by precipitation diminishing visual acuity and fogging binoculars.

Our analytic methods accommodate such variability in detection and identification if certain assumptions are met. A robust detection function (Figure 2) satisfied criteria for estimating detection probability. Our methods of accounting for unidentified murrelets assume similar detection and identification rates for each species and, critically, minimal misidentification. Similarity of detection functions between species in each survey year (Appendix A, Hoekman et al. 2013a) supports our assumption of equivalence of detection and identification rates between species. Although species misidentification rates are unknown, depressed identification rates during 2012 resulted in part from our preference to classify murrelets as unidentified unless high confidence in species identity existed. This approach avoids the relatively high risk associated with misidentification (Hoekman et al. 2011c). Together, this evidence supports the reliability of 2012 estimates.

Restricting sampling relative to sea state presents a trade-off: poor viewing conditions may depress species identification rates and could possibly increase misidentification, but limiting sampling to more favorable conditions prolongs surveys, which can be problematic because of limited availability of personnel and equipment and problems associated with murrelets moving within and in/out of the survey area. We feel our current survey protocol reasonably balances these concerns, but monitoring observer performance relative to weather conditions may inform future protocol revisions.

KIMU spatial distribution

Previous SEAN surveys have not consistently documented high occurrence of KIMU in fjord heads. Instead, KIMU generally have been most numerous in the middle portion of the west arm, the Hugh Miller-Scidmore Complex, and various locations within the main bay. Reid Inlet has been the only location where KIMU concentrations have consistently been associated with a tidewater glacier. Although KIMU were found throughout the bay in 2011 and 2012 , distributions in 2012 were more concentrated in the upper west arm of the bay, particularly in and around Reid Inlet and Russell Island (Figure 4). Distributions from 2009-2012 have generally been consistent with June surveys from 1999-2003 (Drew et al. 2008, Piatt et al. 2011), but have been less consistent with the close association of KIMU with glacially-influenced habitat in Prince William Sound (Kuletz et al. 2003, Kuletz et al. 2011).

Our sampling design seeks to maximize precision of KIMU population estimates by allocating sampling intensity in proportion to expected densities of KIMU (see Hoekman et al. 2013b; Appendix B). Correspondence between expected densities and observed encounter rates was high for 2011 and very high for 2012 surveys. In contrast, peak encounter rates in 2010 were in the mid- to lower bay, areas of moderate expected densities. Despite substantial variability in KIMU distributions, our allocation of effort has generally been successful in increasing sampling of areas with elevated KIMU densities. However, because of extreme variation in KIMU distributions over our (Hoekman et al. 2011a,b; Hoekman et al. 2013b) and other prior surveys (Romano et al. 2007, Drew et al. 2008, Kirchhoff et al. 2010), the potential remains for not observing large concentrations of KIMU actually present within Glacier Bay because they are outside of the study area, using areas that were not sampled during surveys, or absent from a transect during a survey. Such variability may decrease precision and increase inter-annual variation among population estimates (Table 2, Figure 3).

Density estimates

SEAN KIMU density estimates from line transects during 2009 to 2012 (range 6.4-14.1 individuals/km^2) are much higher than from strip transect surveys during 1999-2003 (range 1.8-5.0; Piatt et al. 2011) and 2009 (4.1; Kirchhoff et al. 2010). These differences may be attributable to both the highly dynamic nature of KIMU distributions and methodological differences. Critically, strip transect surveys assume complete detection and likely underestimated density to an unknown degree (Hoekman et al. 2011b). KIMU densities from line transect surveys in 2007 (3.4, Kirchhoff 2008) and 2008 (4.5; Piatt et al. 2011) were similarly low, but an estimate from 2010 (8.9, Kirchhoff and Lindell 2011) was much higher and similar to ours (11.4). Density estimates for MAMU have followed a similar pattern, with estimates for 2010-2012 (range 44.9-

63.1; Table 2, Kirchhoff and Lindell 2011) far exceeding those from 1999-2009 (range 6.4-26.5; Table 2, Drew et al. 2008, Kirchhoff 2008, Kirchhoff et al. 2010; Piatt et al. 2011).

Recommendations

After the 2016 survey, a periodic review will assess population abundance and trend, performance of analytic methods, and ability of the monitoring program to achieve its objectives. Although monitoring success will largely depend on variability in murrelet populations within the survey area, our results and experience to date demonstrate that key operational components of our protocol are functioning as intended: equipment and personnel have been sufficient for timely completion of surveys; species identification rates have been adequate; procedures, equipment, and software for data collection have functioned well; detection probability has been high and detection functions have been robust; and our methods for allocating survey effort have generally been successful in increasing sampling where KIMU density is high. We recommend continuing efforts to improve species identification and distance estimation skills of observers and monitoring effects of environmental conditions on observer performance. As part of the 2013 field effort, SEAN will be cooperating with USFWS and University of Montana to estimate murrelet species misidentification rates for survey observers across sea and weather conditions.

Literature Cited

Arendt, A. A., K. A. Echelmeyer, W. D. Harrison, C. S. Lingle, and V. B. Valentine. 2002. Rapid wastage of Alaska glaciers and their contribution to rising sea level. Science 297:382–386.

Arimitsu, M. L., J. F. Piatt, M. D. Romano, and T. I. Van Pelt. 2011. Status and distribution of the Kittlitz's Murrelet in Kenai Fjords, Alaska. Marine Ornithology 39:13–22.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, New York, New York, USA.

Day, R. H. 1995. New information on Kittlitz's murrelet nests. Condor 97:271–273.

Day, R. H., K. J. Kuletz, and D. A. Nigro. 1999. Kittlitz's Murrelet (*Brachyramphus brevirostris*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online. Available at http://bna.birds.cornell.edu/bna/species/435.

Day, R. H., and D. A. Nigro. 2000. Feeding ecology of Kittlitz's and marbled murrelets in Prince William Sound, Alaska. Waterbirds 23:1–14.

Day, R. H., A. E. Gall, A. K. Prichard, G. J. Divoky, and N. A. Rojek. 2011. The status and distribution of Kittlitz's Murrelet *Brachyramphus brevirostris* in northern Alaska. Marine Ornithology 39:53–63.

Drew, G. S., S. G. Speckman, J. F. Piatt, J. M. Burgos, and J. Bodkin. 2008. Survey Design Considerations for Monitoring Marine Predator Populations in Glacier Bay, Alaska: Results and Post-hoc Analyses of Surveys Conducted in 1999-2003. Administrative Report. U. S. Department of the Interior, U. S. Geological Survey, Reston, Virginia, USA.

Hoekman, S. T., B. J. Moynahan, M. S. Lindberg. 2011a. Monitoring Kittlitz's and marbled murrelets in Glacier Bay National Park and Preserve: 2009 annual report. Natural Resource Report NPS/SEAN/NRR—2011/440. National Park Service, Fort Collins, Colorado, USA.

Hoekman, S. T., B. J. Moynahan, M. S. Lindberg. 2011b. Monitoring Kittlitz's and marbled murrelets in Glacier Bay National Park and Preserve: 2010 annual report. Natural Resource Report NPS/SEAN/NRR—2011/441. National Park Service, Fort Collins, Colorado, USA.

Hoekman, S. T., B. J. Moynahan, M. S. Lindberg, L. C. Sharman, and W. F. Johnson. 2011c. Line transect sampling for Murrelets: Accounting for incomplete detection and identification. Marine Ornithology 39:35-44.

Hoekman, S. T., B. J. Moynahan, W. F. Johnson, and C. J. Sergeant. 2013a. Glacier Bay National Park and Preserve Kittlitz's murrelet monitoring protocol: Version KM-2012.1. Natural Resource Report NPS/SEAN/NRR—2013/735. National Park Service, Fort Collins, Colorado.

Hoekman, S. T., C. J. Sergeant, and W. F. Johnson. 2013b Monitoring Kittlitz's and marbled murrelets in Glacier Bay National Park and Preserve: 2011 annual report. Natural Resource Technical Report NPS/SEAN/NRTR—2013/811. National Park Service, Fort Collins, Colorado.

Kirchhoff, M. D. 2008. Methodological considerations for at-sea monitoring of *Brachyramphus* murrelets in Glacier Bay, Alaska. Alaska Department of Fish and Game, Douglas, Alaska, USA.

Kirchhoff, M. D. 2011. A review of selected surveys of the Kittlitz's murrelet *Brachyramphus brevirostris* in Alaska: Lessons learned. Marine Ornithology 39:77–83.

Kirchhoff, M. D., M. Smith, and S. Wright. 2010. Abundance, population trend, and distribution of marbled murrelets and Kittlitz's murrelets in Glacier Bay National Park. Audubon Alaska, Anchorage, Alaska, USA.

Kirchhoff, M. D., and J. R. Lindell. 2011. Population abundance, trend, and distribution of marbled and Kittlitz's murrelets in Glacier Bay, Alaska. Final Report, GLBA-00141 and -00154 Glacier Bay National Park, Bartlett Cove, Alaska, USA.

Kirchhoff, M. D., J. R. Lindell, and J. I. Hodges. In Press. From critically endangered to least concern?—A revised population trend for Kittlitz's murrelet in Glacier Bay, Alaska. Condor: Ornithological Applications.

Kissling, M. L., P. M. Lukacs, S. B. Lewis, S. M. Gende, K. J. Kuletz, N. R. Hatch, S. K. Schoen, and S. Oehlers. 2011. Distribution and abundance of the Kittlitz's Murrelet in selected areas of southeastern Alaska. Marine Ornithology 39:3–11.

Kuletz, K. J., S. W. Stephensen, D. B. Irons, E. A. Labunski, and K. M. Brenneman. 2003. Changes in distribution and abundance of Kittlitz's Murrelets *Brachyramphus brevirostris* relative to glacial recession in Prince William Sound, Alaska. Marine Ornithology 31:133-140.

Kuletz, K. J., C. S. Nations, B. Manly, A. Allyn, D. B. Irons, and A. McKnight. 2011a. Distribution, abundance, and population trends in the Kittlitz's Murrelet *Brachyramphus brevirostris* in Prince William Sound, Alaska. Marine Ornithology 39:97–109.

Kuletz, K. J., S. G. Speckman, J. F. Piatt, and E. A. Labunski. 2011b. Distribution, population status and trends of Kittlitz's Murrelet *Brachyramphus brevirostris* in Lower Cook Inlet and Kachemak Bay, Alaska. Marine Ornithology 39:85–95.

Madison, E. N., J. F. Piatt, M. L. Arimitsu, M. D. Romano, T. I. Van Pelt, S. K. Nelson, J. C. Williams, and A. R. Degange. 2011. Status and distribution of the Kittlitz's Murrelet *Brachyramphus brevirostris* along the Alaska Peninsula and Kodiak and Aleutian Islands, Alaska. Marine Ornithology 39:111–122.

McDonald, T. L. 2003. Review of environmental monitoring methods: Survey designs. Environmental Monitoring and Assessment 85:277–292.

Moynahan, B. J., W. F. Johnson, D. W. Shirokauer, L. C. Sharman, G. Smith, and S. M. Gende. 2008. Vital sign monitoring plan: Southeast Alaska Network. U. S. National Park Service, Fort Collins, Colorado, USA.

Piatt, J. F., M. L. Arimitsu, G. S. Drew, E. N. Madison, J. L. Bodkin, and M. D. Romano. 2011. Status and trend of the Kittlitz's Murrelet *Brachyramphus brevirostris* in Glacier Bay, Alaska. Marine Ornithology 39:65–75.

R Development Core Team. 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at http://www.R-project.org

Romano, M. D., J. F. Piatt, G. S. Drew, and J. L. Bodkin. 2007. Temporal and spatial variability in distribution of Kittlitz's murrelet in Glacier Bay *in* J. F. Piatt and S. M. Gende, editors Proceedings of the Fourth Glacier Bay Science Symposium: U.S. Geological Survey Scientific Investigations Report 2007-5047 US Geological Survey, Reston, Virginia, USA.

Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99:262–278.

Thomas, L., S. T. Buckland, E. A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R. Bishop, T. A. Marques, and K. P. Burnham. 2010. Distance software: Design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47:5-14.

U. S. Fish and Wildlife Service. 2013. Endangered and Threatened Wildlife and Plants: 12-Month Finding on a Petition To List Kittlitz's Murrelet as an Endangered or Threatened Species, Proposed Rule. (Oct 3, 2013) Federal Register 78(192): 61764-61801. Retrieved October 17, 2013, from http://www.fws.gov/alaska/fisheries/endangered/pdf/kittlitzs_murrelet_pr_oct_2013.pdf.

NPS 132/122657, October 2013

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov